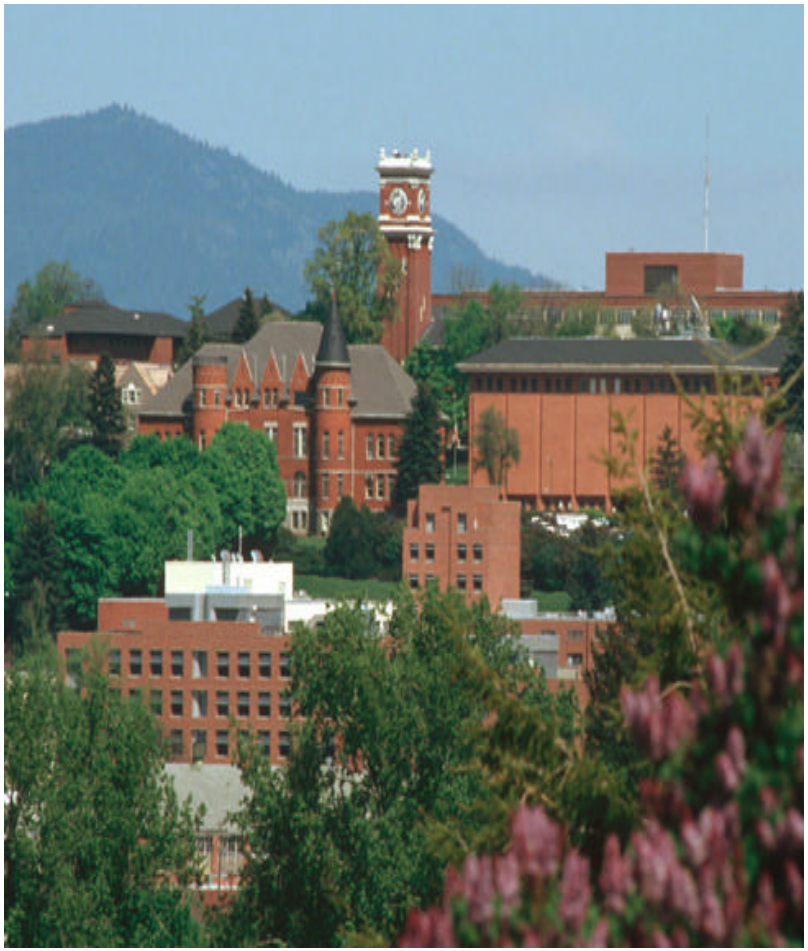
Transmission Reliability Research Review



Feasibility of Real Time Control

Anjan Bose
Kevin Tomsovic
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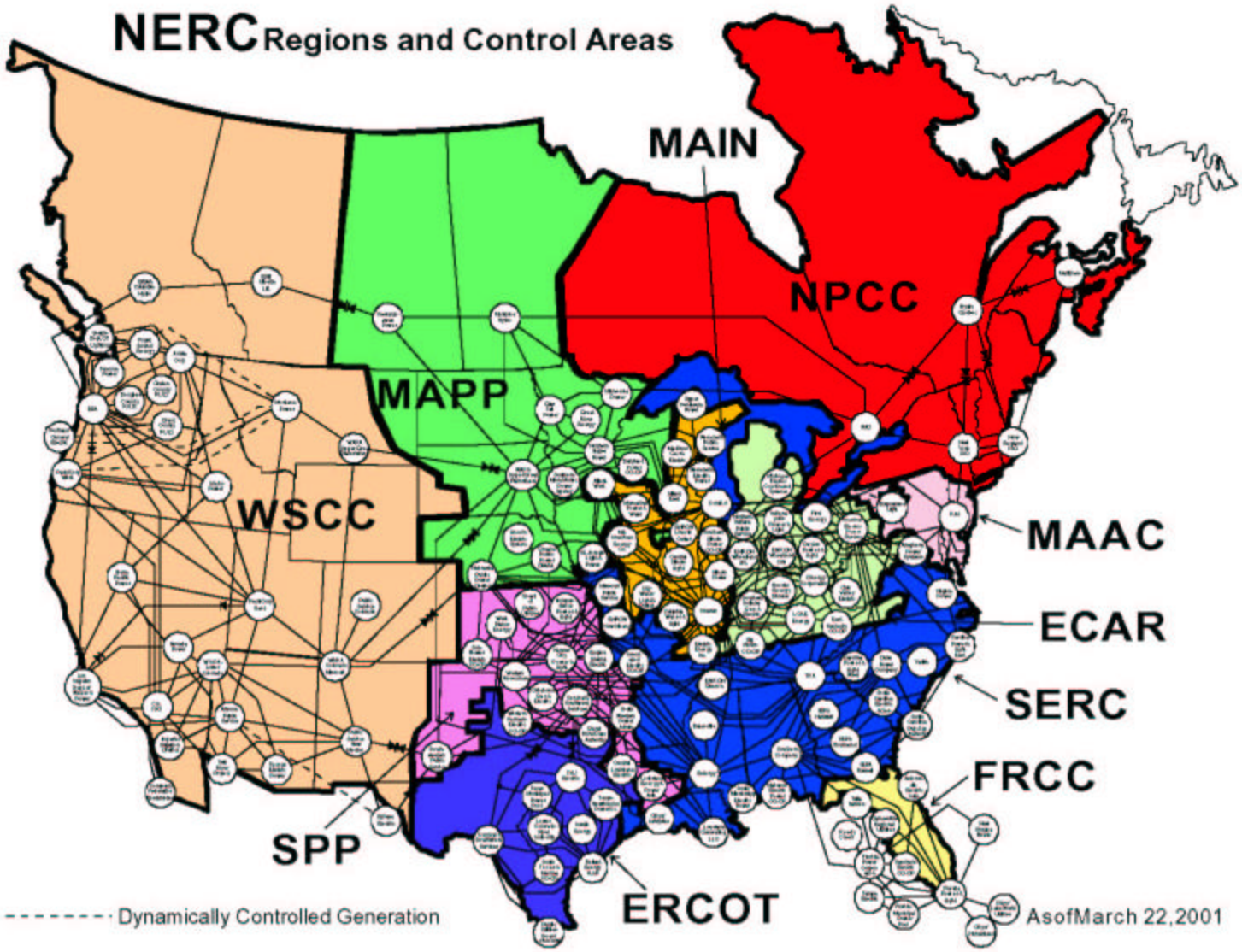
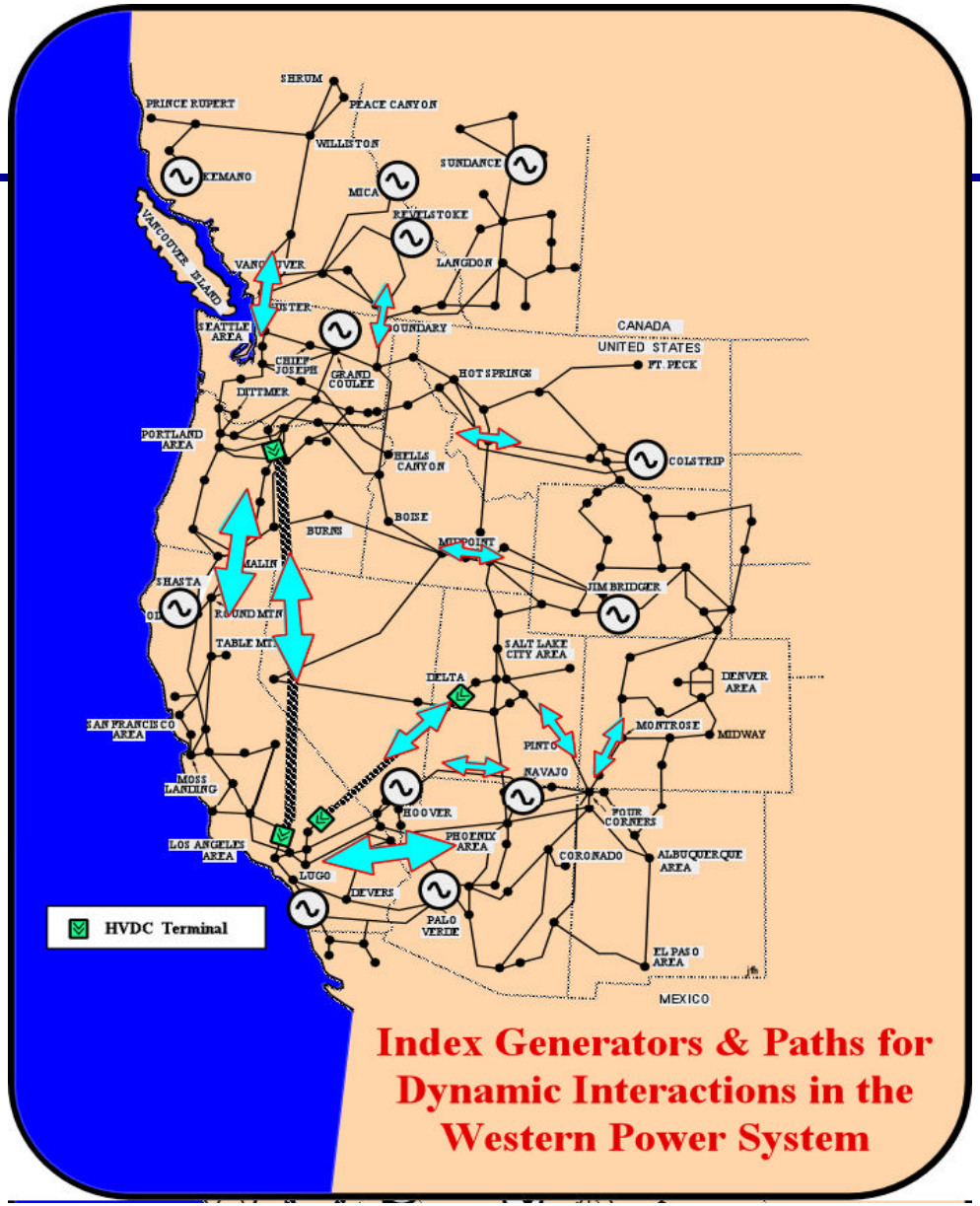
Washington State University

January 27-29, 2004
Washington, DC

CERTS
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS


NERC Regions and Control Areas
MAIN
NPCC
MAPP
WSCC
MAAC
ECAR
SERC
FRCC
SPP
ERCOT
Dynamically Controlled Generation
AsofMarch 22,2001



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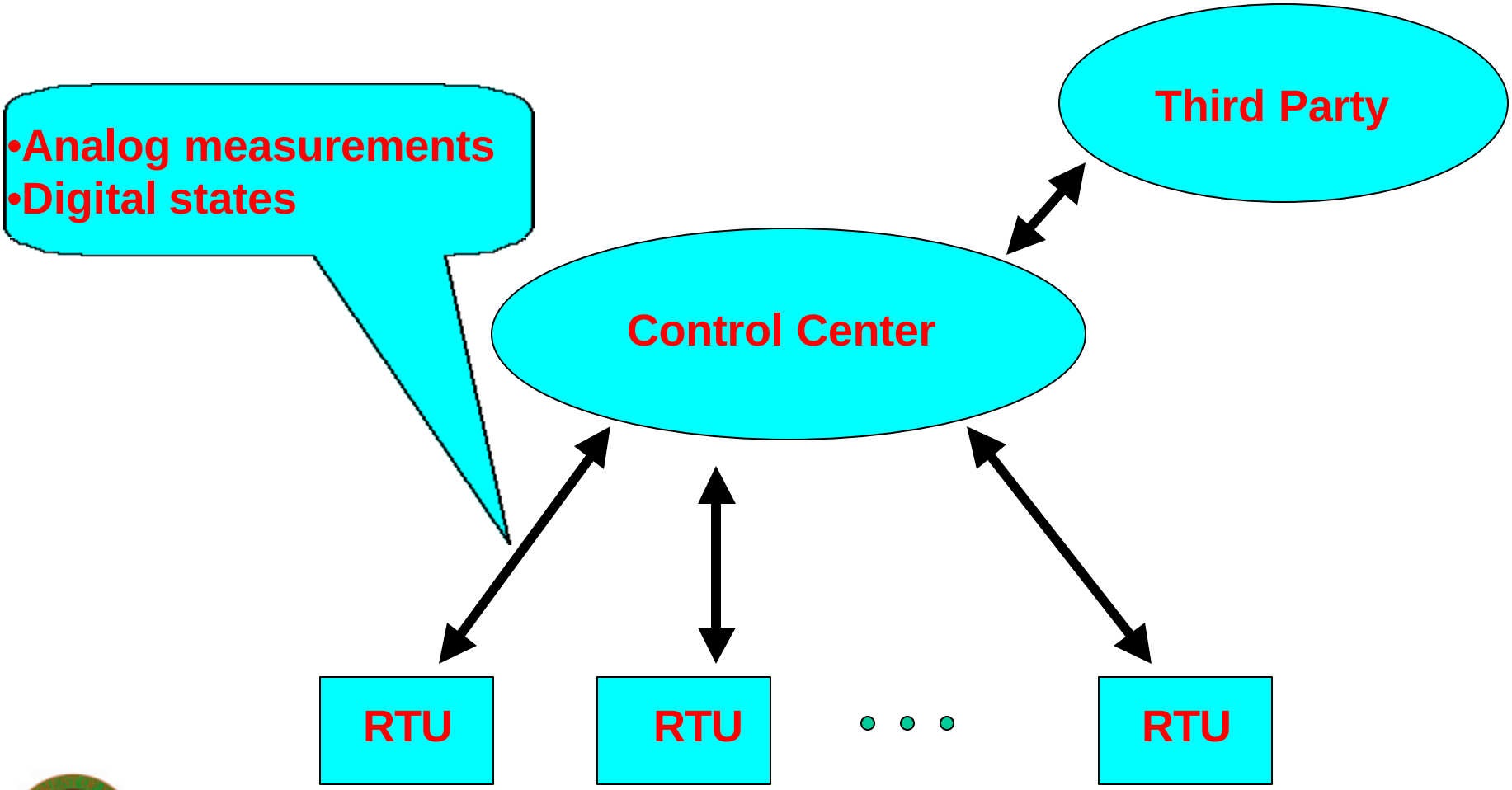
Control of the Power Grid

- Load Following – Frequency Control
  - Area-wise
  - Slow (secs)
- Voltage Control
  - Local
  - Slow to fast
- Protection
  - Local (but remote tripping possible)
  - Fast
- Stability Control
  - Local machine stabilizers
  - Remote special protection schemes
  - Fast

Communication for Power System



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Monitoring the Power Grid

- Alarms
  - Check for overloaded lines
  - Check for out-of-limit voltages
  - Loss of equipment (lines, generators, feeders)
  - Loss of communication channels
- State estimator
- Security alerts
  - Contingencies (loading, voltage, dynamic limits)
  - Corrective or preventive actions

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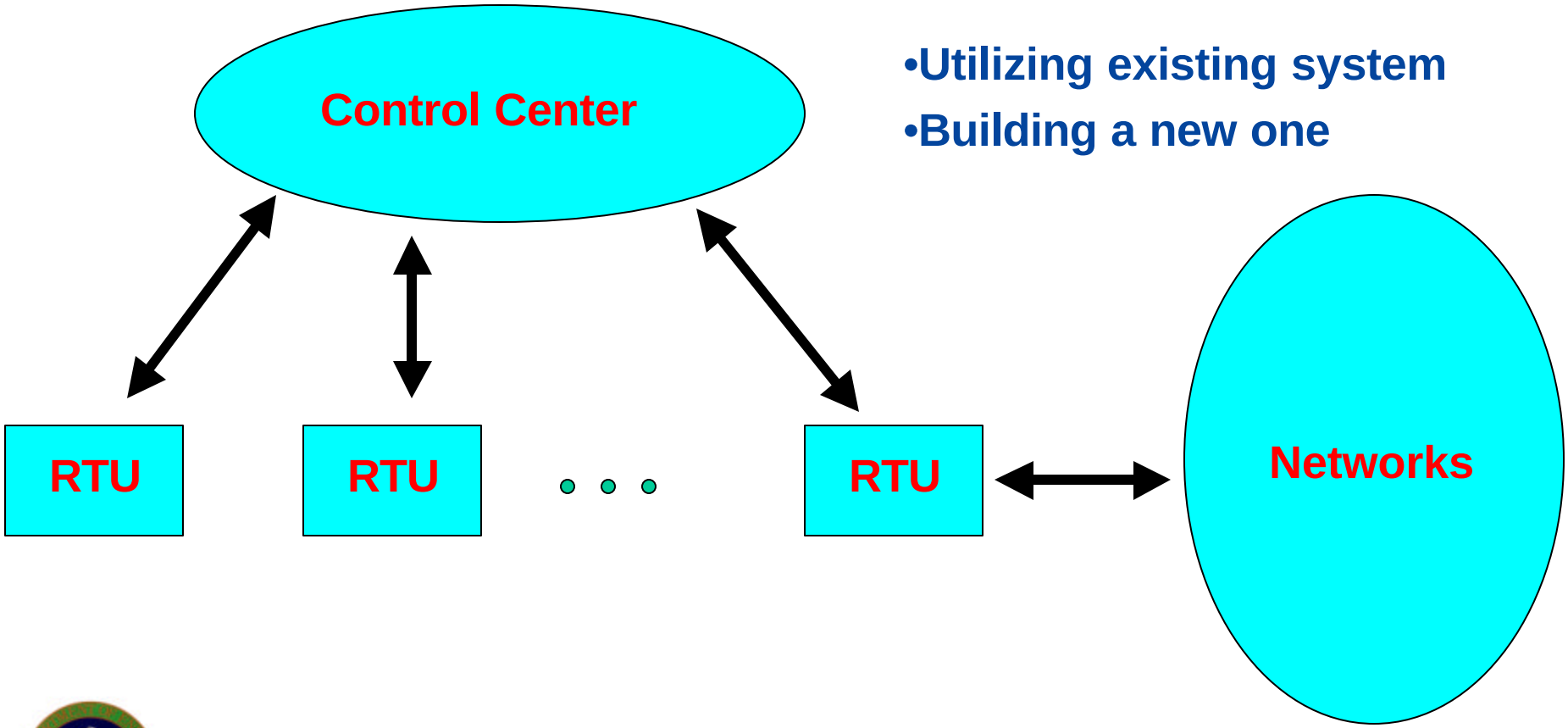
Substation Automation

- Many substations have
  - Data acquisition systems at faster rates
  - Intelligent electronic devices (IED)
  - Coordinated protection and control systems
  - Remote setting capabilities

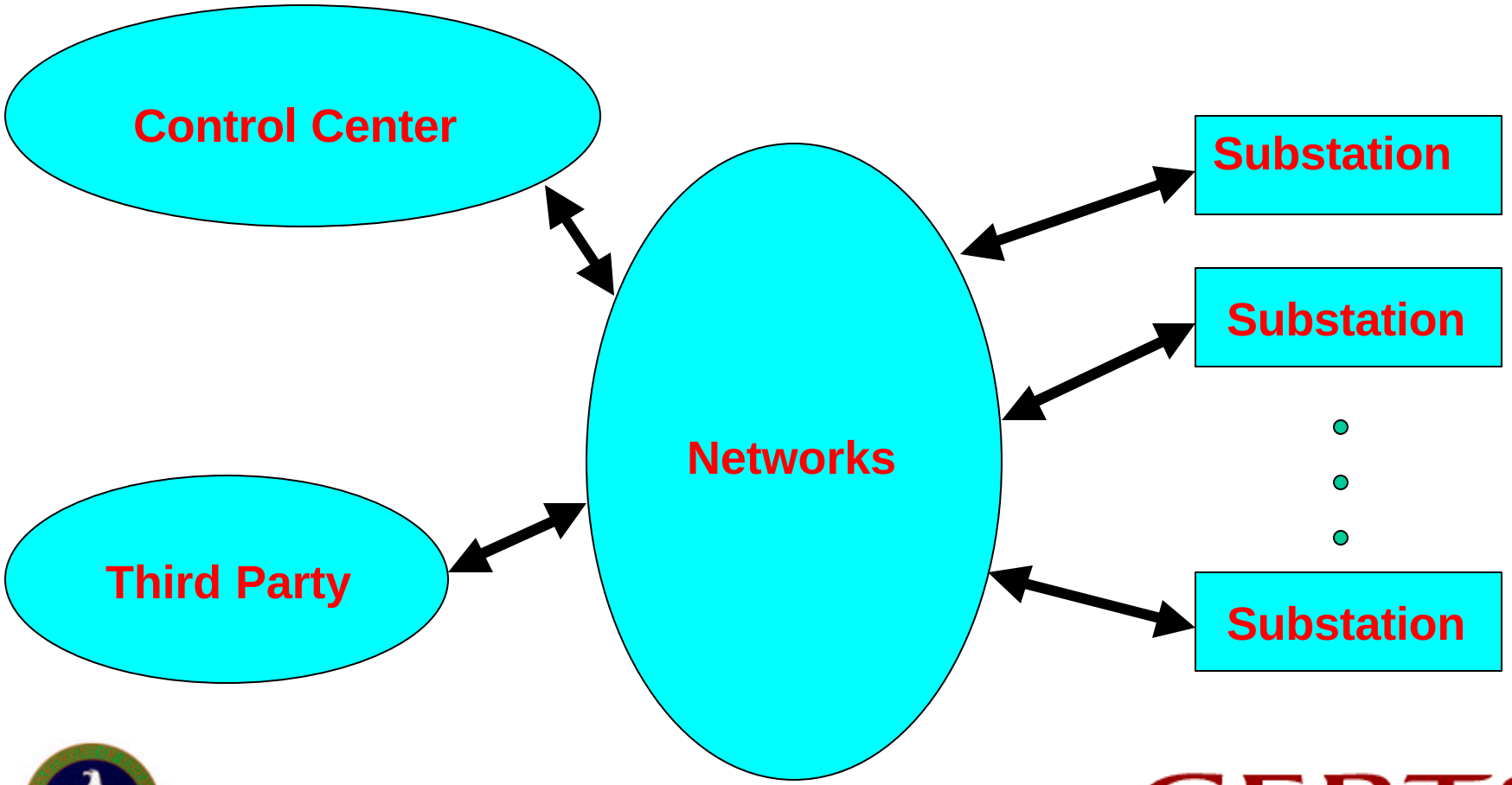
- Data can be time-stamped by satellite

Evolution of Communication System



- Utilizing existing system
- Building a new one

Communication for Power System (future)



WSU Real Time Control Project

- Study feasibility of different levels of area-wide real time controls for the restructured power system
  - Slow controls
    - Automatic Generation Control (AGC)
    - Voltage control
  - Adapting special protective schemes (SPS) or remedial action schemes (RAS) for stability
  - Real time stability control using soft-computing – neural networks, pattern recognition, etc.
  - Real time stability control (the holy grail)

Status of Project

- First Year results (2001)
  - Work on slow controls – AGC
    - Framework for decentralized third-party AGC developed
    - Control feasibility shown with simple communication
    - AGC using open network communications developed
    - New AGC using Linear Matrix Inequality proposed
  - Work on slow controls – voltage control started

Second year results (2002)

- New AGC using LMI shown to be more robust against data delays
- Secondary voltage control shown feasible
  - Create voltage control areas using electric distance
  - Control generator bus setpoints
  - Shown to be feasible by simulation of US Northwest
  - Method suitable for ancillary market

Second year results (contd)

- Coordinated voltage control of generators and switching devices
  - SCADA measurements screened for voltage alarms and circular VAR flows
  - Select candidate local control devices by electrical distance computation
  - State estimation based power-flow model used for computing incremental effects of switching
  - Computation restricted to local area around the control device
- BPA planning to implement method

Third year results (2003)

- Secondary Voltage Control
  - Feasibility of ancillary voltage control market shown feasible for local voltage control area
- Fast Real-Time Wide-Area Controls
  - Practical platform designed for BPA for stability and voltage control
  - Stabilizing scheme by controlling UPFCs shown effective for unstable Italian grid case
  - Fast calculation of generation/load shedding for damping unstable oscillatory modes

Third year results (contd.)

- Fast identification of topology errors using a double pass DC state estimator
- Fast estimation of generator dynamic state from terminal measurements
- Coordination of path transfers to stay within limits by fast OPF formulations – tested on Calif-OR Intertie (COI)

Work Initiated in 2003

- Reviewed presently available ‘hard-wired’ RAS controls
- Modeling and simulation of communication networks employing a publisher-subscriber architecture started
- Completed study of specific RAS controls on the WSCC, including communication models, that look at time available and required generation drop
- Studying flexible RAS controls, detailing failure scenarios and communication network requirements
- Developing flexible RAS approach that determines the amount of load and generation shedding based on the disturbance

Some Research Issues

- Theoretical basis for control issues that incorporate communication and computation
- Simulation tools that incorporate control, communication and computation
- What is a reasonable framework of the communication system for the power grid
- What controllers (FACTS) will be readily available to consider in such wide-area control
- We should be ready with practical control schemes in anticipation of the technology

Publications

- 1. E. Nobile, A. Bose and K. Tomsovic, “Feasibility of a Bilateral Market for Load Following,” *IEEE Transactions on Power Systems*, Vol. 16, No. 4, Nov. 2001, pp. 782-787.
- 2. S. Bhowmik, K. Tomsovic and A. Bose, “Communication Models For Third Party Load Frequency Control,” *IEEE Transactions on Power Systems*, in press.
- 3. X. Yu and K. Tomsovic, "Application of Linear Matrix Inequalities for Load Frequency Control with Communication Delays," *IEEE Transactions on Power Systems*, in press.
- 4. E. Nobile and A. Bose, “A New Scheme for Voltage Control in a Competitive Ancillary Service Market,” Power Systems Computation Conference, Seville, Spain, June 2002.
- 5. Y. Chen, and V. Venkatasubramanian, “Automatic On-line Controller for Coordinated Slow Voltage Control”, *IEEE Transactions on Power Systems*, accepted subject to revision.
- 6. Y. Chen, and V. Venkatasubramanian, “Transient Excitation Boosting Based on Remote Signals”, *IEEE Transactions on Power Systems*, accepted subject to revision.
- 7. J. Zhong, E. Nobile, A. Bose and K. Bhattacharya “Localized Reactive Power Markets Using the Concept of Voltage Control Areas,” *IEEE Transactions on Power Systems*, in press.

Publications (contd.)

- 8. K. Tomsovic, D. Bakken, V. Venkatasubramanian and A. Bose, "Designing the Next Generation of Real-Time Control, Communication and Computations for Large Power Systems," submitted to *Proceedings of the IEEE*.
- 9. C.W.Taylor, D.C.Erickson, K.E.Martin, R.E.Wilson, and V. Venkatasubramanian, "WACS- Wide-area stability and voltage control system: R&D and on-line demonstration," submitted to *Proceedings of the IEEE*.
- 10. S. Bruno, M.DeBenedictis, M. LaScala and A. Bose, "A Dynamic Optimization Approach for Wide-Area Control of Transient Phenomena," Conference Internationale des Grands Reseaux Electriques a Haute Tension (CIGRE), Paris, France, August 2004.
- 11. G. Zhao and V. Venkatasubramanian, Fast tuning procedures for emergency controls
- using eigenvalue computations, Conference on Electric Supply Industry in Transition, Sponsored by AIT and PSerc, Bangkok. Thailand, January 2004.
- 12. V. Venkatasubramanian and R. Kavasseri, Direct computation of generator dynamic states from terminal measurements, 36th Hawaii International Conference on System Sciences, Hawaii, January 2004.
- 13. L. Xu, K. Tomsovic and A. Bose, "Topology Error Identification using a Two-State DC State Estimator," submitted to *IEEE Transactions on Power Systems*.
- 14. Y. Li and V. Venkatasubramanian, "Coordination of transmission path transfers," *IEEE Transactions on Power Systems*, in press.